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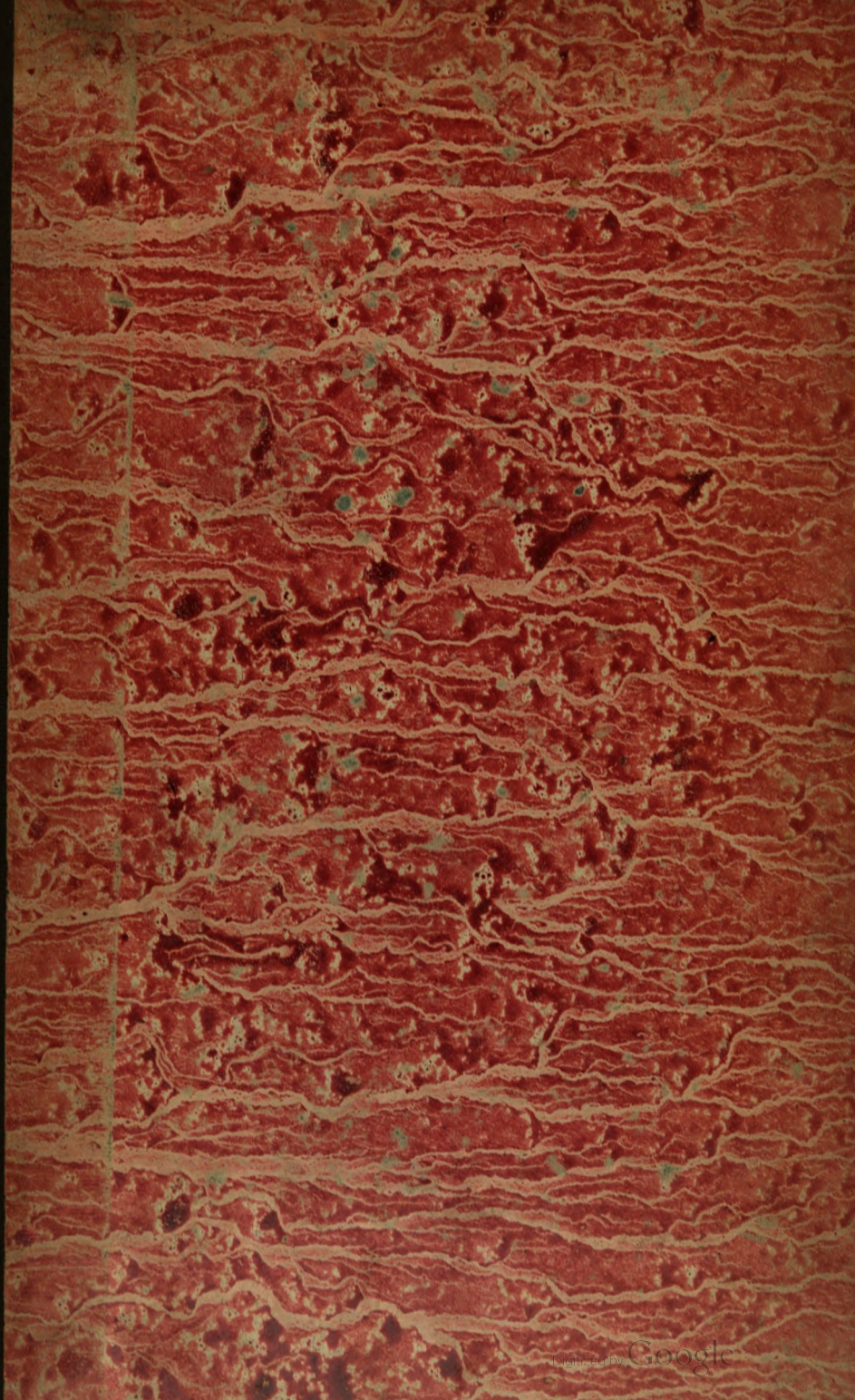
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EXPERIMENTAL RESEARCHES
ON THE
IDENTITY
OF
THE VARIOUS MODIFICATIONS
OF THE
ELECTRIC FLUID.

BY JOHN GOODMAN, M.R.C.S.L.

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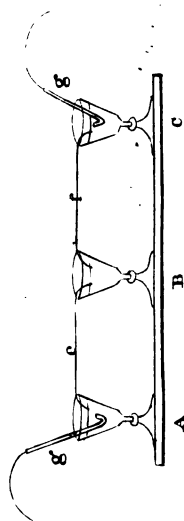
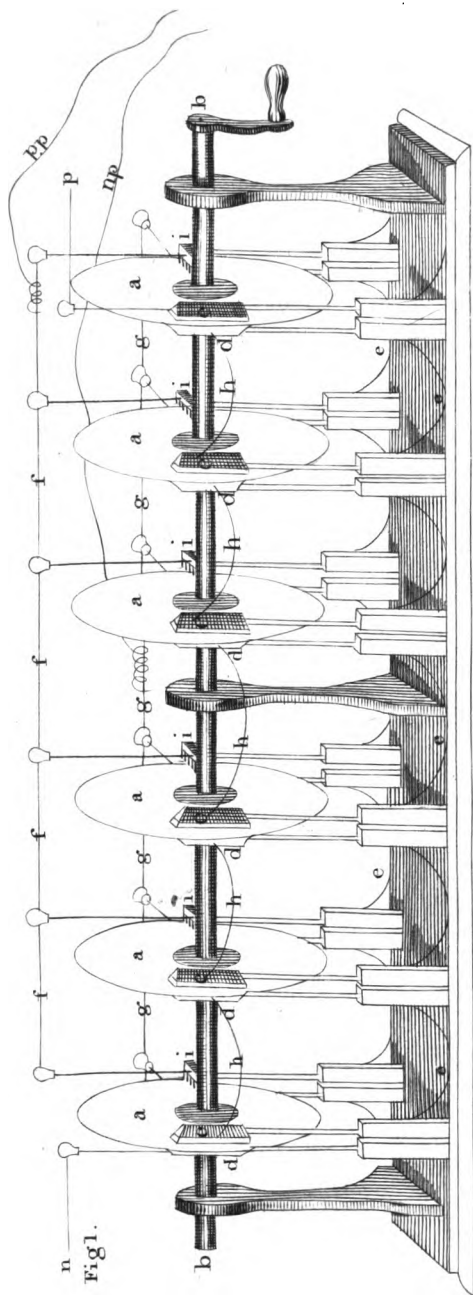


Fig. 2.

APPARATUS FOR POLARIZING FRICTIONAL ELECTRICITY.

1851 Dec 2

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ON THE MODIFICATIONS OF THE ELECTRIC FLUID.

On the Identity of the Ordinary and Voltaic Electricity. By
J. GOODMAN, Esq., M.R.C.S., &c.

Read at the Royal Victoria Gallery of Practical Science, Manchester, at
the Conversazione, October 22nd, 1840.

1. The views of electricians which have been so long entertained with regard to the identity of the electricities, the galvanic, frictional, and magnetic, appear to have commanded and obtained almost universal assent. The experiments, however, upon record, which I have hitherto perused, such as those of Dr. Wollaston, and others, and the more recent ones of Dr. Faraday, although manifesting in a high degree the analogy of galvanic and ordinary electricity, are still not perfectly decisive, and for reasons which will be hereafter adduced, have impressed me with the necessity of still further carrying on the inquiry. I doubt not but to many minds the experiments of the illustrious individuals above named may appear finally conclusive and satisfactory; but if there still remain those who are discontented, unless the two fluids so tested be submitted to exactly similar circumstances, be tested by indeed the same apparatus, effect chemical and other changes in precisely the same quality of materials, evince the government of the same laws in its conduction, insulation, polarity, &c., (see 41. 42. 44. 45.) and be indeed moulded into a perfectly identical form of fluid; if in the substance of the ensuing paper experiments be found which can add satisfaction to, and set the matter finally at rest in the minds of the latter class of individuals, this, and this alone, will fulfil the objects of the following investigation.

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Jan 1841, 412

2. On first surveying the distinctive characters of the two fluids, we find a wide unbounded contrast, and an unlimited diversity of properties. On the one hand our attention is directed to the roaring and tempestuous burst of fluids from the most extensive, immense, and immeasurable distances, polarizing, as it were, heaven and earth at the same moment, and traversing with fleetest strides the remote boundaries of the terrestrial and celestial empire; devastation, destruction, and ruin, marking frequently the footsteps of this subtle agent; whilst the other is silently, slowly, and almost imperceptibly executing the most beautiful, useful, and interesting productions of the material universe. It appeared that to attempt the establishment of identity between fluids of such opposite characters, it would become necessary to endeavour to mould the one under investigation, as nearly as possible, to the characters and properties of the opposing kind.

3. The subject which appeared least satisfactory, and which has induced me more particularly to commence a further inquiry, is, the decomposition of water by ordinary electricity; an experiment which it is well known has so frequently been accomplished by the galvanic fluid. For although this decomposition had been effected by many individuals, I am not aware that the gases were ever collected in a completely separate state, and submitted to a perfect analysis, and if we contemplate the manner in which the experiment has generally been performed, it has been without any reference to the character of the fluid imitated, and, as may be gathered from some of the following experiments, with mostly unsatisfactory results. (38. 43.) I doubt not, therefore, I shall be excused the boldness of my attempt, in *endeavouring* (although the subject has failed in the hands of the eminent) to establish the analogy of these fluids by experiments which have at all times been looked upon as possessing the most decisive character.

4. Finding, on the onset of my enquiry, the *tension* of ordinary electricity, in comparison with that of the most powerful voltaic battery, to be very much superior, and that this property may be instantly diminished (as will be shortly exhibited) (see 14) by charging a Leyden jar, I determined upon at once drawing out a statement of the properties of the galvanic and frictional electricities, to direct and guide me in all my future experiments.

5. Galvanic electricity, for instance, as existing in a common battery, or single pair of plates, usually presents the following properties or characters:—1. It is produced in a *continuous stream* of one or two fluids of opposite kinds, one positive, the other negative.—2. The two streams or currents of positive and negative electricities have a constant and mutual attraction for each other, there being a continual tendency of the *positive*

fluid to pass to the negative body, and to no other.—3. The galvanic fluid is subject to the influence of induction, or polarization of the most *contiguous* kind, being produced by the assumed oppositely electrical conditions of the atoms of matter when in *absolute contact*, and hence the *tension* of this fluid or its capability of passing through a non-conducting medium, is *exceedingly limited*, and may also be termed *atomic*.—4. It is conducted badly by metals, and scarcely at all by water.—5. Its *attractive and repulsive* powers are also of the *feeblest* kind, for without a considerable number of alternations of plates, gold leaves cannot be diverged, nor any effect produced upon the pith ball or other electrometers.—6. Its physiological effects are very feeble in proportion to the quantity of the fluid, nor are they experienced at all unless contact of the poles be made and broken.—7. The poles of this fluid do not require insulation, a consequence of No. 2 and 3.—8. Its *quantity* is exceedingly great, and far surpassing the amount of fluid generated by an ordinary electrical machine.—9. It is incapable of being accumulated in the shape of charge; one instantaneous contact with the coating of a Leyden jar being productive of as great an amount of electric fluid as the continuation of the same for any length of time, its quantity being alone obtainable in a continuous current.—10. By increasing the polarizing influence by a given number of alternations, *tension* becomes apparent, is rendered evident by the passing of a spark and other effects, and by still further augmenting this influence, a greater degree of tension is obtained, altogether, however, much inferior to the effects of this kind in the ordinary electricity.

6. If we now proceed to contrast these peculiarities of the galvanic fluids with the modified forms of fluid under which frictional and aerial electricity appear, we find that the fluid termed lightening, and that which passes in sparks from the machine, differ most widely from the properties herein described. Now it is singular that these very forms of electricity should have been almost the only kinds made use of in the investigations of philosophers in imitating the galvanic action, and it is also more singular, that in all the experiments (except the first) no negative pole was ever made use of which had a mutual decomposing dependence with the positive, and, consequently, bearing not the slightest resemblance to the properties of the galvanic fluid, especially as described (No. 5. 2.)

7. Dr. Wollaston's experiments were performed chiefly by *sparks* from the machine of various dimensions, and in one instance by *current alone*, but at the same time with only *one* pole, and, says he, "the *appearance* of two currents of air may also be imitated by occasioning the electricity to pass by fine points of communication on both sides of the water, but, in fact, the resemblance is not complete, for in every way in

which I tried it, I observed that each wire gave both oxygen and hydrogen gas, instead of their being formed separately, as by the electric pile." Perhaps it is unnecessary to state that here no mention is made of connecting more than one pole to any electrical body whatever.

8. In 1807 Sir H. Davy immersed a guarded platina point connected with the machine in distilled water, and dissipated the electricity from the water into the air by moistened filaments of cotton. In this way it is stated that he obtained oxygen and hydrogen separately from each other.

In 1832, the late Mr. Barry communicated a paper to the Royal Society, stating to have decomposed water by electricity, and to have obtained separate oxygen and hydrogen, from a kite-string in communication with one wire or pole, whilst the other wire was merely connected with the ground.

10. In the experiments of Dr. Faraday, (I believe our latest authority upon this subject) as stated in his series of experimental researches in electricity in 1833, in the decomposition of water, it is stated, (329) "if with a constant pair of points the electricity be passed from the machine in sparks, a certain portion of gas is evolved, but if the sparks be rendered shorter, less gas is evolved, and if no sparks be passed, there is scarcely a sensible portion of gas set free. On substituting solution of sulphate of soda for water, scarcely a sensible quantity of gas could be procured, even with powerful sparks, and nearly none with the mere current. (330.) "When what I consider the true effect only was obtained, the quantity of gas given off was so small that I could not ascertain whether it was as it ought to be, oxygen at one wire and hydrogen at the other."

11. As the other decompositions performed by this celebrated philosopher appear to have been accomplished by attaching the positive pole to the prime conductor, and the negative to the "discharging train," (321) it is not improbable that the decomposition of water was attempted by him in the same manner, but the fact is not stated. With regard to the experiment of Sir H. Davy, Dr. Faraday adds in a note to (471) series 5, that "it does not remove any of the objections I have made to the use of *Wollaston's apparatus as a test of true chemical action*;" of the one quoted by Barry, he remarks, (339) "nor have any of the numerous philosophers who have employed such an apparatus obtained any such decomposition either of water or of a neutral salt by the use of the machine;" also, (342) "Mr. Barry's experiment is a very important one to repeat and verify. If confirmed, it will be, as far as I am aware, the first recorded case of *true electro-chemical decomposition of water by common electricity*." A very similar remark is also made by him. (359.)

12. It is apparent from what is recorded of these experiments

that no attention was ever paid to the properties of galvanic electricity described (No. 5. 2.) viz., of providing poles dependent one upon the other for decomposing power and action. The positive pole was at all times connected to a positively charged body, but the negative pole was attached to matter, either in the natural state of electrization (speaking of it as a mass) as in the case of the "discharging train" used by Dr. Faraday, the "ground" by the late Mr. Barry, the "air" by Sir H. Davy, &c., or in a negative state to which the fluid from the positive pole had no special tendency to pass *the negative conductor*, (see now 45.) of which, nevertheless, we have, I believe no positive statement that it was ever used at all. Dr. Faraday also remarks, concerning the poles used by Wollaston, "that the poles, or rather points, have no mutual decomposing dependence may be shewn by substituting a wire, or the finger for one of them, a change which does not at all interfere with the other, though it stops all action at the charged pole."

13. On examining the modifications of the electric fluid derived from the machine, or lightning, we find it existing in two very opposite conditions, determined by the distance of polarizing bodies, or the thickness of the insulating medium through which the polarization is effected. Thus lightning and the sparks from the machine (the kinds generally employed by electricians in imitating galvanic decomposition) are subject only to *very distant* polarization, (see No. 5. 3.) and may be denominated *free electricity*, from their capability of passing to *any* body in their vicinity, (see No. 2.) having no tendency to pass to one conductor more than another, except from contiguity, being in an *interrupted* stream or streams (see No. 1,) possessing the most *unbounded tension*, (see No. 3,) powerful, attractive, and repulsive powers, (see No. 5,) conducted excellently by metals and with great facility by water, (see No. 4,) Physiological effects only when the current is broken or intensity very great, (see No. 6.) Insulation essential to its very existence, (No. 7.) Its quantity is exceedingly small, (No. 8.) but can be accumulated to any amount. (No. 9.)

14. The *tension* obtained by the influence of this polarization gives to the fluid *considerable mechanical force* and *powerful momentum*, and by the expansive character thus obtained, the pressure of the atmosphere, and of water (when passing through that fluid) is more forcibly resisted and sustained. By this means an exceedingly *minute* quantity of electricity may be rendered visible by expansion (17. b) and may appear to the observer as fluid of great quantity, and "high intensity" (17. a) The influence by which this modification of electricity is governed, I have named *remote polarization*, and when this kind of electricity is submitted to the action of *polarizing* influence of the proximate kind within its immediate neighbourhood,

as in the *coatings of a Leyden jar* or other thin insulator, we find that the spark from the prime conductor which was capable of passing one inch, under these circumstances, will now only pass one-twentieth of that distance. The fact is instantly shewn by first taking a spark from the prime conductor, and observing the passing distance and the height of an electrometer in connection with the machine. If now a Leyden jar of any kind be connected to the conductor, the electrometer instantly falls, and the passing distance of a spark will be reduced to, at least, one-twentieth of its former magnitude. I find, also, that with the interposition of electrics of various thicknesses very different effects are produced. Thus with a passing distance of one-tenth of an inch and a very thin laminae of mica, *three* discharges only passed in one turn of the machine, the electrometer being at 11 of an arbitrary scale. With glass one-thirtieth of an inch thick—and the same passing distance—31 discharges occurred in one turn, the electrometer being at 16 degrees. (See also 23. 24. 25.)

15. The *tension*, therefore, is by this means *considerably diminished*. 1. The production of fluid under this influence in a continued stream (5. 1.) presented many difficulties, but will be described further on in the paper. 2. The mutual attraction of one pole for the other, when attached to these polarized coatings or surfaces, and the tendency of the fluid of the positive to pass to the negative and no other, (as in 5. 2.) are very manifest. 5. The attractive and repulsive powers are also diminished. 4. It is much less easily conducted by water, and even metals, than any quantity of electricity under remote polarization. 6. The physiological effects are feeble where only a current exists, but manifested by making and breaking contact. 7. The poles do not require insulation, in consequence of No. 2. 8. The quantity may be rendered greater than that from the machine alone, (of which hereafter.) 10. By increasing the polarizing influence by a given number of alternations of jars, tension is considerably augmented.

16. From the knowledge of the extensive modification of the ordinary electricity thus effected by inductive influence, I have been induced to divide the *polarization* of electricity into three kinds: 1, The contiguous, or atomic; 2, The proximate; and 3, The remote.

17. In passing, it would be well to define the meaning of the terms *tension* and *intensity*, which I have adopted in this paper, since it appears that very different constructions are commonly appended to these important terms. (a) I observe Dr. Faraday speaking of *tension* and *intensity* (series 12—1370) as of *one* and the *same property*, (see index *tension* 1370, *intensity* 1370,) also series 4, (392) ordinary electricity termed “electricity of *exalted intensity*,” and (419) electricity of “*high tension*.” I

find in another publication, Henley's electrometer described as for the purpose of measuring "the intensity of the electricity." I also meet with in another work, that one of the principal circumstances in which *voltaiic* differs from *ordinary electricity* is "*the very low state of intensity in which it exists in the former when compared with the latter.*" Now the terms appear to me to denote two electrical conditions very different from each other. (b) By the term tension (or any meaning I can attach to it) appears to be understood polarizing power, transferring force, capability of passing, a forcible stretching or expansion *from the centre towards the circumference*; and this appears to me to apply admirably to the nature of ordinary electricity, as obtained from the prime conductor, "electricity of high tension." (c) But by the term intensity I should understand condensation, or concentration *from the circumference towards the centre*, that of large quantity reduced to a very small compass, thus a burning lens condenses the rays of the sun, so as to bring them to a focal centre, where the highest degree of intensity of heat is experienced. This property is also exhibited by the *quantity* voltaic battery, where a fine platina wire is interposed in the current, it becomes immediately red hot, and is retained at a red heat so long as the battery continues in action. The same may be said of the passage of an ordinary electrical battery charge, through such a wire, a large quantity of fluid is in this instance also compressed into the narrow limits of a small conductor, and exhibits its intensity by rendering the wire momentarily red hot. If the quantity of fluid be augmented, or wire diminished, a greater intensity of effect will be the result, as shown frequently by fusion of the conductor.

18. From this view of the subject, therefore, it would appear that intensity has nothing to do with the properties of a spark from an ordinary electrical machine. With a given quantity of electrical charge, the tension (or capability of passing) from the polarizing to the polarized body or surface, will be in ratio with the distance of the two polarized bodies. (a) Thus the tension (or passing distance) of contiguous polarization is atomic; of a Leyden jar, under proximate polarization, the distance of the thickness of the glass; of the fluid from the prime conductor, under remote polarization, the distance of a body in which it is capable of inducing a given polarity; of the fluid from a cloud (also under remote polarization) to the earth, &c. (b) Now the tension of all these electrical forces under similar circumstances, will be continually the same, according to the source whence each is derived. (c) Thus, if electricity be excited by a small machine, a spark of given dimensions will be the result in a given time, and it will be impossible to obtain from the same machine, under the same circumstances, a spark of greater magnitude. If a large machine also produce a given spark, a similar one may *cæteris paribus* at any time be obtained.

(d) Charge a jar by means of the spark so obtained, which will now become its source, and the result will be a spark as just exhibited diminished at least to 1-20th of its original dimensions, and it is impossible, by any means, to obtain afterwards the fluid so polarized, in dimensions greater than that to which it is now reduced by polarization. (e) I doubt not, but fluid submitted to the influence of atomic polarization would, under the same circumstances, give *atomic distances*, which afterwards could not *ceteris paribus* be increased. (f) Combine a number of electrical machines, and an increase in the *quantity*, and to some extent in the tension will be the result. (g) But the method by which the passing distance or tension of ordinary electricity is most considerably increased, *after proximate polarization* of that fluid, is by the combined influence of a number of polarized surfaces. If six insulated jars, connected by conductors, so that the outside coating of the first shall communicate with the inside of the second, outer of second with inside of third, and so on throughout the series, be charged, by connecting the first jar with the prime conductor, the outer coating of the last being in connexion with the negative conductors, an explosion from the inner coating of the first to the outer lining of the last will take place about *six times as far* as from any two surfaces of a single jar by the ordinary method of discharging. Tension, therefore, is diminished in ratio with the *degree* of contiguity of polarization, increased by quantity, and greatly increased by reciprocal polarization.

19. In pursuing my experiments, I obtained permission to make use of the large plate machine in the Manchester Royal Victoria Gallery; a plate whose diameter is about five feet, having four rubbers, and considered a first rate machine; sparks of ten inches in length may be readily obtained from the prime conductor when in good order. On attempting to decompose water by the current alone (as hereafter) with this machine, I was exceedingly surprized to find little, if any, more gas eliminated from the poles than could be obtained by my own machine, the cylinder being only fourteen inches in diameter. I have since been led to the conclusion, *that probably the thickness of the glass* in the electrical machine, determines the passing distance, or tension, momentive force, and size of spark, (see 14.)

One surface of the glass receiving, by friction, an encreased quantity of electric matter not naturally belonging to it, induces polarization of the "molecules" (Dr. Faraday) throughout the whole substance of the glass, and causes the development of free, undisguised fluid on the opposite surface. If the electricity be now collected from the latter surface, the electric would be left in the condition of a charged Leyden jar; one surface positive and one negative.

But if the fluid be collected from the charged surface alone, (as is usual,) the *disturbed fluid* at the opposite surface, together with the *forced condition of the molecules*, would conjointly tend to induce the removal of the fluid from the charged surface with a *force in ratio with* the amount of polarized molecules, or *thickness of the electric* which they compose. (see 14. 19. g.)

20. Apply these ideas and facts to voltaic electricity. It is produced and still continues under the influence of atomic polarization. Take one pair of plates, for instance, the passing distance is atomic. By increasing the size of the plates, as in the quantity battery, or adding a number of plates in which there shall be a connection of all the zinc together, to form one pole, and of all the copper plates to form the opposite pole, the quantity *shall be much increased*, and the tension or passing distance *slightly so*. (17. f.) But if (as is well known) a number of alternations of plates be so arranged, that the first positive plate (the copper one) be in conducting communication with the second negative one, (zinc) a non-conducting medium be interposed between the two, the second plate with the third negative, and so on through the series, by which the various alternations are placed in the most advantageous position for aiding and assisting each other, (reciprocal polarization,) a considerable increase of tension, or passing distance, will be the result; a few alternations will readily manifest the electric spark, and a very large number exhibit electric attraction and repulsion, and produce a brilliant spark, attended with the most splendid exhibition of electric light in existence, and with a tension equal to about 1-30th of an inch in cold, and three or four inches in heated air. (17. g.) With these views I proceeded to the practical application of the subject.

On the Analogy of Ordinary and Voltaic Electricity.

21. Finding that ordinary electricity, under the influence of proximate polarization, approaches nearer in character to the voltaic than any other modification, I proceeded to decompose water by means of an apparatus in which the principle of the Leyden jar formed the most prominent feature. I at first made use of uncoated wires, as in the experiment by M. M. Paets, Van Troostwyk, and Deiman, and although bubbles of gas did make their appearance upon the platina wires, there is every reason to believe them to have consisted entirely of carbonic acid gas, since the water made use of at that time was pump water, and the gas ceased to make its appearance after a very short period. Very shortly afterwards I coated fine platina wires (reduced to a moderately fine point) with glass, by inserting them in tubes, and melting the glass around, and grinding whilst the point appeared, &c., as in Wollaston's experiment. After several trials, I found that one Leyden jar insulated, its

internal being in communication with the positive, and its external with the negative conductor, produced the greatest quantity of gas, one pole being connected to the outer coating, and a wire from the other placed at such a distance from the knob of the jar, that the electricity would pass in small and very rapid shocks. By this means I obtained from one pole, on the 14th of July, in about an hour, 2-3rds of an inch of gas in a small tube receiver; the quantity in the tube situated over the other pole did not at the close of the experiment contain near so much gas, but in testing the former by passing an electrical spark through it, it exploded, and left about one-third its original bulk, so that there would be probably (supposing the remainder to be hydrogen) two parts oxygen to seven hydrogen in the whole amount, i. e. (considering the whole to be nine parts) three remained and four hydrogen exploded, with two of oxygen.

22. About the same period I completed an increasing battery upon the principle of the six jars already described, and by a little contrivance of two rotatory rods, A. B., from which projecting wires alternately came in contact with and discharged the whole series, through the two guarded poles by shocks. (1, 2, 3, 4, 5, 6.) By this means a very rapid decomposition of water was effected—two-thirds of an inch of gas in the hydrogen tube could now be produced in from twenty minutes to half an hour, but by passing a spark, the *instantaneous disappearance of nearly the whole amount of gas* in the tube *was the result*, shewing clearly that the decomposition was of mixed gases at each pole. I found, also, that the poles in this experiment had “no mutual decomposing dependence,” as stated by Dr. Faraday concerning the decomposition by Dr. Wollaston, and that any other conductor in connection with the outer coating of the jar did not interfere with the formation of gas at the opposite pole; therefore each pole is of itself by shocks capable of decomposing. (See now 43.)

23. In pursuing the subject of proximate polarization, according to the rule of distance already laid down, I was in search for a material of nonconducting properties which would allow the two polarizing surfaces to approach as nearly as possible, and by this means I was in hopes that effects might be produced very much resembling those of the galvanic electricity. Indeed I was inclined at one period to imagine that no decomposition of water identical with galvanic could be obtained, unless we could subject the electric fluid to the atomic polarization. The material which I fixed upon was the thinnest lamina of mica which it was possible to produce by slitting, as is usual in microscopic experiments. I placed a small bit of tinfoil on its upper and under surface and charged it. On testing its physiological powers, I found that a quarter or half a turn of my machine

produced by this means a charge which shook the elbows violently. The power, indeed, of the machine appeared considerably heightened in contrast with the effects of the thinnest charged phial I could meet with. The very smallest distance of break in the circuit (apparently contact) at which a ball could be placed from the positively charged coating, gave constant shocks and sparks between the balls, so that here we have an excellent illustration of one of the propositions where it is stated (14.) that proximate polarization diminishes the tension of the machine, one-twentieth or more. The prime conductor from which this was charged will at any period (when in moderate order) give sparks from two to three inches; but by being in contact with two almost contiguous polarizing surfaces, the spark will not pass the 1-100th of an inch until the mica be charged, and it is only the distance now which the so charged mica has tension enough to pass which regulates the period of discharging.

24. By the polarized mica and guarded platina poles, I succeeded in decomposing water apparently much more rapidly than by any other means. By an experiment with a given passing distance of two balls (3-10ths inch apart) the charge of a jar exploded by one turn of the machine, and with the same distance (the jar being removed) twenty sparks passed in one turn with the same apparatus, but a very fine lamina of mica being interposed instead of a jar, the discharge would not pass at all, and in six turns the lamina was pierced by explosion and destroyed. With the mica I obtained *eight* distinct shocks, felt in one finger of each hand up to the wrist, during one turn—the passing distance being about 1-50th of an inch.

25. With the Leyden jar instead of the mica, (the jar being 1-20th inch thick) I placed the balls at a distance apparently imperceptible, perhaps 1-80th inch, and obtained distinct shocks, and this afterwards by contact, the lacquer of the balls alone intervening. In this last experiment we learn that polarization of glass can be effected to a much greater distance than discharge through air; the fluid will more readily polarize to the distance of 1-20th inch than pass 1-80th, or even the distance of the lacquer covering the balls.

26. On the 21st of July, I passed 3-4ths inch *sparks* through the decomposing apparatus, and obtained a decomposition of water, but on contrasting it with the quantity obtained through the medium of a small Leyden phial, the discharges occurring as frequently as the sparks for a given number of turns of the machine, I obtained about double-sized globules of gas, from the discharges of the phial, to what were obtained by the simple spark alone. When the spark was made use of no *star* appeared upon the apex of the pole, as is always the case when a Leyden discharge is made use of. Upon attempting to decom-

pose by the *current alone* without any break in the circuit, and with the *poles as yet made use of, no gas* made its appearance at either pole. It may be well here to remark that through a fine platina point, in which the electricity is forcibly confined to the limits of the most minute conductor, if an attempt be made to pass a shock of any magnitude, the constricting portion of glass is instantly and forcibly removed, and the platina laid bare for a considerable portion of its length, so that the pole by this means becomes utterly useless.

27. From the results of these experiments the idea suggested itself that a twofold condition of each pole, one during, and the other instantly after, the passage of the electric discharge of *spark or shock* might occur, and by this means be the reason why oxygen and hydrogen were found products from each pole. This idea was also somewhat strengthened by finding that Dr. Faraday discovered a two-fold condition of an electro-magnetic wire, and opposite effects from the same, upon making or breaking contact see series 1st—(11, 14, 15, &c.) “The slight deflection (says he) of the needle occurring at the moment of completing the connection, was always in one direction, and the equally slight deflection, produced when the contact was broken, was in the other direction.” To prove the same by experiment I first charged a jar, insulated as usual, and connected to the positive and negative conductors, having first appended a wire pole to each coating, terminating in a ball, and about three-quarters of an inch apart, and to and at the end of the negative, a slender wire terminating in a pith ball. The ball was repelled from its perpendicular by excited wax until the discharge passed, when it was instantly attracted and retained (still out of its perpendicular) by the wax for a short period, thus manifesting a negative state of the negative pole, during the charge, and a positive or natural state of the same during, or instantly after, the passage of the contents of the jar. I next suspended a pith ball by a glass thread in the vicinity of the negative pole of the jar; during the charging of the jar the ball adhered firmly to the termination of the pole, but instantly on discharging the jar, the pith ball forcibly separated, and was repelled to a distance, and found to be attracted by excited sealing wax. By this experiment also, a two-fold condition, first negative and then positive, of the pole in contact with the outer coating of the jar, is pretty fairly exhibited. Finally, I procured an electroscope, (a pith ball terminating the extremity of a fine glass filament, which filament was supported by a needle point, insulated, and thus allowing the rotation of the filament upon its axis), this I arranged between the two terminating balls of the Leyden jar—the ball of the electroscope became positively electrified and pointed constantly to the negative terminating ball during the charging of the jar—but instantly on the explosion taking place, the pith ball was repelled

towards and attracted by the positive terminating ball, sometimes as near as possible, but contact was purposely prevented; This was invariably the case during a dozen or more repetitions of the experiment. Upon applying excited sealing wax the pith ball was attracted strongly, shewing the same to be positively electrified. In all these experiments the ball was first attracted to the positive pole—it then receded a little until the residuum was discharged, after which a permanent attraction was the result. The most rational method of accounting for the alternately opposite electrical condition of each pole is by supposing the charge to pass in a globular volume. Thus:—

Fig. 1, $\overline{pp.} \quad \underline{p} \quad \quad \quad \underline{n} \quad \quad \quad \overline{np}$

Fig. 2, $\overline{pp.} \quad \underline{n} \quad \quad \quad \overline{p} \quad \quad \quad \underline{np}$

By the Franklinian hypothesis.

During the passage of the charge at the termination of the positive pole p , the opposing end of the negative pole n , would be negativated by the polarizing influence of p . But the moment the charge arrives at n (represented by p , fig. 2) the termination of the positive pole would be negativated by the inductive influence of the charge at p , fig. 2.

23. If, then, the poles of a Leyden jar be alternately positive and negative, or negative and positive, which has been already seen, there is no difficulty in explaining why oxygen and hydrogen gases are formed at each pole, and independently of each other. If it is found that the negative pole of a voltaic battery invariably sets at liberty hydrogen gas—the positive pole oxygen, and each pole of the Leyden jar be alternately negative and positive, or *vice versa*, the decomposition by the latter with mixed hydrogen and oxygen gases at each pole, is identical with the principles of decomposition exhibited by the voltaic apparatus; for if from each pole a single gas should be alone obtained, the pole itself being continually changed, the effect would be indeed “different from that of the galvanic phenomena.” It appears, therefore, that by the use of sparks or shocks, or indeed any break in the electrical current, we do not produce a decomposing effect truly identical with that of the voltaic battery, there being mixed gases eliminated by each pole.

(To be continued.)

On the Identity of the Ordinary and Voltaic Electricity. By
J. GOODMAN, Esq., M.R. C.S., &c. (continued from page 13.)

Read at the Royal Victoria Gallery, November, 1840.

29. To imitate the electro-chemical actions of the galvanic fluid by ordinary electricity, we are obliged, as before stated, to proceed in our experiments with a *perfectly continuous current*, and, for reasons hereafter to be mentioned, to obtain a view of the gas generated, (40, 43) to confine the current in conductors of a most limited magnitude.*

30. It appears to me there have been two principal causes why analogical decompositions have not been effected. The first has been that a sufficiently fine and delicate diameter has not been given to the conductors or guarded poles; (26) (Wollaston's method of constructing such as would decompose by current alone being difficult and tedious he first obtained a nitro-muriate of gold in solution, placed the same in a glass tube, melted the tube with the blow-pipe, by which means he also evaporated and drove away all the acid, and then, by drawing out the tube, rendered the metallic lamina of gold exceedingly minute. His results, however, being, on certain accounts, unsatisfactory, as has already been pointed out.) The magnitude of the poles being too great, has induced the experimentalist, from the great paucity of fluid in the ordinary electric current, to *separate some* portion of the conducting material and *produce sparks or shocks* in the circuit, and thus render gas visible where none can be obtained by the mere current, which, as shown in my last, destroys the identity of effect of the two fluids, (21.22.27).† The second cause of failure has generally been the *deficiency in quantity* of the current fluid—producing such scanty developement of gas—that it would have been folly in the operator to have attempted to procure as much as could be submitted to the test of explosion by the electric spark.

31. The method which I found necessary to adopt in the construction of the guarded poles, was the following:—I procured a proportion of the finest platina wire obtainable in town, *hammered its extremity* until it formed a flat plate, whose area was about 10 or 12 times the diameter of the wire; and with a pair of scissars *cut it into as fine a point and filament as possible*, and placed the wire in a small glass tube, melted the extremity until it adhered to and covered the filament, and afterwards by grinding exposed the point sufficiently *for a small spark from the machine just to pass*—which point could by no means be discovered either with the naked eye or a microscope. A curve was also given to the lower part of the glass tube, see g. g. fig. 2.

* This applies only to the guarded poles, (26) see now 47.

† See Dr. Faraday's 3rd series, (329)

32. Finding the electro-chemical powers of the current alone from the machine exceedingly low, I became desirous of availing myself of the powers of the increasing battery, before described. (22). But the great difficulty of discharging a succession of *charges* in such a manner as to produce a continuous current appeared insurmountable. Meanwhile proceeding to construct a machine for the purpose of producing the two kinds of electricity upon the opposing surfaces of an electric in the state of proximate polarization, (14.15) imagining that by this means the quantity might not only be augmented, but a fluid more nearly resembling the galvanic produced. I mounted a circular plate of common window glass upon an axis similar to a plate machine. One side of the plate was covered with a layer of sealing-wax, and a rubber of hair skin applied to it in communication with the ground. On the opposing surface a rubber of leather with amalgam, was made use of, &c. In all ways in which the same could be tested, I obtained vitreous or positive electricity upon each surface, which fluid also could only be collected on one side. The reason was obvious. The positively excited surface by polarization caused the development of the natural fluid belonging to the opposite surface, (in defiance of hair skin, sealing-wax, or any other resinous exciting electric)—as in the phenomena of the Leyden jar or plate machine, (19).

33. The failure of this experiment, nevertheless, put me in possession of a method of obtaining a continuous current from the increasing battery. I remembered that the Leyden jar, with moveable linings, can be charged positively and negatively on its surfaces, the coatings can be then removed, and a slow and gradual discharge of the whole of its fluid produced by connecting the inner and outer surface of first one portion and then another by the common discharging rod. It struck me that a modification of this experiment might readily fulfil the object desired. Removing from the glass plate, already described, the rubbers, and in place of them applying two metallic moveable coatings, c d, fig. 1, in imitation of the Leyden jar, I charged the surface by one coating positively, and removed the natural positive fluid from its opposing surface by connecting the other coating with the insulating negative conductors of my machine. The *fluid from the charged surfaces* was collected by two other insulated metallic coatings, to which were attached two metallic poles. On receiving the fluid through each hand, I was delighted to find an entirely novel physiological effect. The sensations produced by the electro-magnetic machine were exactly imitated. I proceeded to effect electro chemical decomposition, and obtained my first decomposition of water by this machine, (21) but the quantity of fluid in the ordinary electrical current being so exceedingly low, now induced me to take ad-

vantage in its construction of the principles of the increasing battery already described, (18 g, 22.) I procured six plates like the one in question (except the coating of sealing wax), see plate fig. 1, a a a a mounted them on an insulating axis, b. b. b, and applied twelve moveable coatings, c. d. c. d. &c. as in the last described apparatus. The first coating was placed in connection by the wire p. with the positive conductor of the machine—its outer surface and coating d being in communication by the wire h with the inner surface of the next plate at c, the disturbed natural fluid was given to the latter—and so on throughout the series. The last surface was also deprived of its fluid by connecting the wire n with the negative conductors of the machine. By this method, however, it was found that the expected accumulation of fluid could not be obtained, the great distance of polarization required, on account of the thickness of the glass, being too much for the powers of my electrical machine, and I have since found that the greatest quantity is produced by dividing the fluid from the prime conductor, and charging in two situations instead of one. I now charge the inner surface of the first—and that of the fourth with positive fluid—and remove the fluid from the outer surface of the third and sixth by communication with the negative conductors. The surfaces thus charged are, by rotation, brought round to the insulated coatings of the poles—all the positively charged surfaces by the medium of f f f f being in communication—and all the negative also connected one to the other by the communicating wires g g g g. To each of these the wire poles p p and n p are attached, and the increased current of fluid so obtained is transmitted through them to any object which it is intended to subject to the action of the current. From its chemical effects, I have reason to believe that the fluid from the machine is by this means increased—(supposing that polarization has no direct influence in decomposition)—(26) to threefold its original amount.

34. I have endeavoured, for some time, to procure *six plates of mica*, of a sufficient magnitude, to enter into the construction of a polarizing machine, which, from its *extreme thinness*, would, I doubt not, augment prodigiously the amount of fluid in the current through the poles—probably 12 or even 24 plates might as easily and as perfectly be polarized as one-eighth their number of common window glass—and the fluid so eliminated would also *resemble much more nearly* (as before remarked) the fluid from a galvanic battery, both in tension, quantity, and all the other properties, as described in the chart, (5).

35. The method of receiving the electric fluid by *moveable coatings*,* as at first adopted, when submitted to the test of chemical decomposition, was found to be as objectional as the

use of the Leyden jar, (22) and sparks, as exhibited in my former paper. The gas generated was found to be a mixture of hydrogen and oxygen at each pole, but more nearly approaching the galvanic decompositions—being at the negative pole *only one-sixth oxygen and five-sixths hydrogen*. This was readily accounted for. *Once or twice* in every turn of the machine, a *distinct shock* could be perceived by its usual diagnostic—the *star* on the platina point—which shock caused the elimination, as before stated, of both hydrogen and oxygen at each pole.

36. I next collected my current at the origin of the positive pole by *needle points*, and the *true* electro chemical decomposition of water appeared now to be obtained, and which has since been established. The appearances, when true decomposition is taking place are as in galvanism. A *constant stream of minute equimagnitudinous bubbles*, issuing from the positive pole in *one continuous thread-like current*, the bubbles from the *negative* in *double size or quantity*, and *there being* in the positive current at *no period an increased bubble*, unless the gas adheres to the termination of the pole. Still, occasionally an accumulation presented itself in the current, and I determined at once to collect the fluid by means of the points (ffff, &c.) in connexion with each individual surface, and thus prevent the occurrence of shock in the current altogether, since no production of pure hydrogen at the negative, or of oxygen at the positive pole could ever be obtained, whilst shocks continued to make their appearance. This being effected, I have now the satisfaction to state that, from the result of decomposition with this machine, the gas is obtained in a manner perfectly identical with galvanic decomposition.

37. In conjunction with Mr. Sturgeon and Mr. Eaton Hodgkinson, on the 13th of October instant, I succeeded in obtaining by this means, in less than two hours' turning, a small bubble of about one-eighth of an inch in length in a tubular receiver. The gas arose from the negative pole from whence hydrogen arises in the voltaic arrangements, and in passing *ten or twenty sparks through it no diminution in the magnitude of the bubble was at all effected*, see (22). On adding a portion of atmospheric air to the same, (no oxygen being collected) and passing a spark, an *immediate diminution* in the volume of the gases was observed, shewing evidently that the former gas was pure hydrogen. At the Victoria Gallery, Nov. 18th, 1840, I passed sparks through two or three portions of gas (hydrogen) already obtained, and no diminution in the quantity could be perceived. On adding a portion of oxygen from the other receiver, and passing a spark, the gas instantly collapsed. It is worthy of remark that one portion of gas exhibited at the Victoria Gallery, *one-eighth of an inch in length in the tube receiver*, was produced in *one hour's turning* by the aid of the *electrical machine alone*. I have reason

however, to doubt the purity of the gas in this case. There must have been a break in the current, but none could be detected, although a suspicious sound of exceedingly minute sparks was perceived and mercury connexions were not used throughout the circuit. When a decidedly unbroken current is employed generally double this length of time is required to produce this quantity of gas. The reason of so rapid a formation of gas was, that a high pressure *steam engine*, was employed in turning the machine, which revolved in consequence steadily, with about three times the rapidity that could have been effected by manual labour. This is indeed the most simple and least expensive method by which these long, and otherwise tiresome and laborious experiments can be performed—and which I now adopt in all researches of this nature.—See Dr. Faraday's 3rd series, (356).

38. I now beg your attention to the statements made by electricians, *some of whom* have, it is said, produced decomposition of water with ordinary electricity, identical with galvanic, in which separate gases are reported to have been given off from the poles; and I think you will agree with me, from facts which I shall shortly exhibit, and others already before you, that if we are to believe their statements, we must at the same time deny that identical decomposition could have been effected by, the methods adopted. See also (11). Dr. Wollaston's experiments were performed chiefly by sparks from the machine, and in one instance, by current alone, with the fine thread of gold already described. But in the philosopher's own words we have a candid acknowledgment that the decomposition was not identical; for, says he, "in every way in which I have tried it, I observed that each wire gave both oxygen and hydrogen gas, instead of their being formed separately, as by the electric pile. Sir Humphrey Davy immersed a guarded platina point, connected with the machine, in distilled water, and dissipated the electricity from the water into the air by moistened filaments of cotton."—(Dr. Faraday, note to 471, series 5.) Had *two poles* been used in this experiment there would have been some plausibility in the stated result, that oxygen and hydrogen were separately obtained. I find, indeed, that what appears to be true decomposition does occur where *two guarded poles* are employed, and the negative terminating in a point and dissipating the electricity into the atmosphere, but I also find that the *quantity of gas* is by this means *much less* than when in connexion with both the positive and negative conductors; and judging from the exceedingly small amount given off in this way, I should be inclined to disbelieve that the gas was obtained in quantity sufficient to be tested in the usual manner. But to suppose that gas would be eliminated from cotton filaments, which, as we gather from the statement, formed the

negative pole, would be very improbable. I should, indeed, from an experiment immediately to be related, (40,43) doubt the reality of any appearance of hydrogen altogether. In the experiment of Mr. Barry, communicated in 1832 to the Royal Society, it appears that he used two tubes, each having a wire within it passing through the closed end, as is usual for voltaic decompositions. Further on in his description we find him stating that the decomposition was performed by lightning, obtained by an electrical kite, and that the intensity of the electricity was exhibited by the "*usual shocks on touching the string*." Now, to attempt to procure decomposition of water and developement of the gases by a wire of moderate dimensions, uncoated, and exposed to the surrounding liquid for its whole length, merely with electricity, the shocks of which any human being could endure, would be, according to all known results, utterly useless. Nor is, I believe, the statement of Barry at all relied upon, see Dr. Faraday, (339, 340, 341, 342). Lastly, Dr. Faraday, 1833, in imitation of the experiments of Wollaston, says, (330) "when what I consider the true effect only was obtained, the quantity of gas given off was so small that I could not ascertain whether it was as it ought to be, oxygen at one wire and hydrogen at the other." "The quantities were so small that on working the machine for *half an hour*, I could not obtain at either pole a bubble of gas larger than a small grain of sand. If the conclusion which I have drawn, (377) (that the chemical power is in direct proportion to the absolute quantity of electricity which passes), *this ought to be the case*." We have, therefore, as it appears upon record, no authenticated case of true electrochemical decomposition of water by frictional electricity. Dr. Faraday, after recording these statements, even doubts (356, 359) the possibility of any common electrical machine having as yet supplied electricity enough in a reasonable time to cause true decomposition, although the plate of the electrical machine with which he performed his experiments was fifty inches in diameter, and from which, according to his own statement, sparks of ten to fourteen inches in length could easily be drawn from the conductors, (see 19, 14).

39. It had frequently occurred to me, that if the union of the galvanic and ordinary electricities could be effected, so as to act in concert in the decomposition of water, a perfect proof of identity might by this means be exhibited. For this purpose I effected decomposition with a voltaic battery of ten or twelve jars, (*couloires de tasses*) by the medium of the guarded platina poles. The formation of gas was exceedingly feeble. The quantity generated by no means exceeded that of decomposition by three polarizing plates with ordinary electricity. I then arranged two wine glasses of distilled water, in which four guarded poles were inserted (two in each) so that there should

be a galvanic and an ordinary electrical pole in each glass, viz., a negative pole from the machine and a positive from the voltaic battery in one glass, a negative from the voltaic battery and a positive pole from the machine in the second glass. Knowing that the voltaic battery could effect no decomposition without an opposing pole, and that the same might be stated of the frictional poles, I believed that if this experiment should succeed, the final identity was perfectly established. The experiment succeeded, and gas was generated by each of the four poles. This occurred on the 18th September. But shortly afterwards I found that a similar effect might take place with the frictional fluid alone, from its exceedingly great tension, the plates and fluid of the battery serving to connect the poles of one wine glass with those of the other, and thus decomposition might take place, (as it were,) in one continuous current from the positive to the negative poles of the polarizing machine. I afterwards found that by six poles thus arranged in the circuit, decomposition went on as well as it had done by two only. Such, indeed, is the *tension* (17.b) of ordinary electricity, that it is difficult to say at what number of poles thus arranged it would effect decomposition. The effect, indeed, seemed to be heightened by increasing the number of poles.

40. Now by this time I was perfectly satisfied that a true decomposition of water was effected not only by the polarizing apparatus, but by the current alone from the electrical machine. Yet as some remarks are made by electricians *objecting to the use of the guarded poles*, I determined upon attempting decomposition by unguarded ones. Dr. Faraday, for instance, states in a note to (p. 133) that the experiments of Sir H. Davy with Wollaston's poles, do not remove any of the objections he has made to the use of Wollaston's apparatus as a test of true chemical action. The objections are as above stated (328)—“That the water is decomposed at both poles, independently of each other.” “That the poles have *no mutual decomposing dependence*, may be shown by substituting a *wire*, or the *finger*, for one of them a change which *does not at all interfere with the other*, although it *stops all action* at the changed pole;” and (337, that the effects with Wollaston's apparatus are probably resulting “*from high temperature acting on minute portions of matter*,” or “*connected with results in air*,” “nitrogen be able to combine directly with oxygen under the influence of the electric spark.” When shocks are sparks are used in the decomposition, water probably may be decomposed by one pole independently of the other, or with no mutual decomposing dependence, there being an elimination of combined gases, as before exhibited, (see now 46). But where a *perfect decomposition is effected* where *oxygen alone* is produced by one pole, to imagine that the *hydrogen* becomes *annihilated*, and decomposition still proceeding, would

be highly unphilosophical. In imitating the related experiments of Sir H. Davy, I found, moreover, that a thick wire substituted in the place of one pole *does not prevent decomposition at the remaining pole, and that gas is eliminated in just the same thread-like stream as before.* I found also that by connecting the thick wire with the ground, in imitation of Barry's experiment, a similar current of gas was still obtained; and yet *none* made its appearance upon the wire substituted for the guarded pole—*oxygen being generated and hydrogen not making its appearance.*

41. Having fortunately in reserve *two hammered platina poles* (31) rendered exceedingly fine, which were constructed for decomposition, and *without any glass or other coating upon them.* I passed the point of one anxiously yet slowly beneath the surface of the water, and when about the eighth of an inch immersed, I had the satisfaction to behold the same speedily covered with minute bubbles—the decomposition proceeding as usual at the guarded pole during the whole period. I speedily removed the guarded pole from its electrical connections—and substituted a second unguarded pole of a similar magnitude, and on turning the machine for a very short period, *both poles were entirely covered with gas, the negative in about two-fold quantity—and thus a decomposition of water was effected perfectly identical with galvanism, and that from the prime conductor of the machine alone, and subject to no objections of electricians on the ground of the metal being coated with non-conducting material,* (see now 49).

42. With these poles I have also decomposed sulphate of copper by current from the machine alone—metallic copper appeared at the negative pole which may also be observed now upon the same—and gas (which I suppose to have been oxygen) was given off continually from the positive—and none from the negative pole.

43. It is not, therefore, difficult to suppose that in the substitution of a *thick wire; the finger, or filaments of cotton,* for the guarded pole, *particles or atomic portions of hydrogen might be continually being deposited upon the surface of the latter, and yet not visible to the naked eye.* For taking into consideration the length of time required for the deposition of bubbles upon the minute unguarded platina pole—whose thickness is but the 960th part of an inch, length immersed *one-eighth*, and total breadth one 96th of an inch, it seemed probable that the length of time required to render bubbles visible to the naked eye, or seen through a microscope upon the whole surface of an unprepared wire, (see now 47, 48, &c.) the finger, &c., might occupy a considerable period. The same reasoning would also, I believe, apply equally to any other conducting body which might be introduced for the purpose of forming a negative pole, or convey-

ing away the electric fluid (if the formation of gas at the opposing pole still remain unaltered), and it is worthy of remark that *without some conducting material no decomposition takes place at all, shewing that there is at least some mutual decomposing dependence.* (4f).

44. By diminishing the powers of the voltaic battery we find perfectly identical results, (a). Thus, if a syphon be interposed between the vessels in which a small galvanic pair of zinc and copper wire is introduced, or a long column of acidulated water between the copper and the zinc by employing a thick copper wire, *ten or twenty minutes is required before any bubbles make their appearance,* especially if it be immersed the depth of an inch or two, (b). Under such circumstances it would not be improbable after waiting ten minutes or a quarter of an hour and no bubbles making their appearance, that an electrician might give up the experiment, imagining that decomposition was not taking place at all, (c). But with a moderately fine platina wire, or the unguarded platina pole, (41) gas is generated and makes its appearance *immediately.* (d) Now any individual seeing this voltaic decomposition or that of the F. E* (41), with the same unguarded pole, I am sure would be utterly unable to point out any difference. (e) From these and other facts I have been led to conclude that in many electrical experiments, where a current appears to circulate through a given amount of water, *no current really passes,* but decomposition takes place upon the whole or part of the surface of the conducting bodies, the *natural electric fluid of the water, affording to them a sufficient supply to cause the re-appearance* of the current at the same—and which decomposition may not be cognizable on account of the time required to render it apparent to the senses; at all events the line of demarcation is not yet laid down, *upon what quantity of metallic surface electro-chemical decomposition is effected by ordinary electricity and where it is not.*

45. If we now refer to the chart (5.) we shall find a remarkable coincidence between the properties of ordinary electricity during decomposition, and the characters of the galvanic fluid, taking into consideration the effects of the electrical machine alone—since, as has been already demonstrated, perfectly identical decomposition can be effected by it, under given restrictions, be effected. 1st. We have now “a *continuous current,*” both by the polarizing machine and by the ordinary method. 2nd. That the currents have a *mutual attraction* for each other, and the poles, *consequently a mutual decomposing dependency,* (in addition to what has already been stated,) is admirably exhibited in the following manner:—Let the *positive conductor* of the machine be in conducting communication with the building, floor, table, or even with the *gas pipes* of the town, the “*discharging train*” of Dr. Faraday, and by which, as is *supposed,* all electrical effects are annihilated; let the *negative conductors*

* F. E. means frictional electricity, and G. E. galvanic electricity.

also be in conducting communication *with any other part of the building not in connection with the latter, and yet decomposition shall still proceed at the decomposing apparatus.* The positive conductor may even be *directly connected with the negative,* providing the *lacquer* of the same intervene and decomposition will be unaffected. By this latter experiment we produce perfect agreement in character with the galvanic fluid, the tension or passing distance *within* the circuit you observe is *atomic* or thereabout—although this machine will give four-inch sparks or more when no decomposition is taking place—(see 5. 3.)—I should say indeed, that the *fluid* under these circumstances is *Galvanic, not ordinary electricity.* 4. Inconducibility by water when decomposing (44. e) 5. No one would doubt at all the *diminished powers in attraction and repulsion* when not a spark can be obtained. Light bodies (pith balls, &c.) may be held indeed in the vicinity of the conducting wires or attached to them without any exhibition of attraction or repulsion. 6. Physiological effects only by making and breaking contact, powerful or not, according to the tensive force. 7. I have just shewn you that F. E. *does not require insulation* more than G. E. 8. I have reduced the quantity of the voltaic current to little more than that of an electrical machine. 9. And lastly as long as the fluid is incapable of passing *at all to any body out of the circuit, we cannot expect any accumulation,* more than by galvanic arrangements. As to the number 10 we have already shewn to what modification it belongs.

46. Not being perfectly satisfied whether the poles would effect decomposition *by shocks* (40) separately, or without any mutual action: I placed two guarded poles in *separate* wine glasses, filled with distilled water, one being in connection with the inner coating, and the other with the outside of an insulated Leyden jar. It did not appear impossible that the two *oppositely electrical conditions* (27) of each pole, might be the means of eliminating oxygen and hydrogen in each vessel independently of the other. Upon attempting to pass shocks, no effect at all could be produced, and not the slightest trace of gas observed. Upon inserting the ends of a copper wire in the glasses to form a communication, decomposition instantly proceeded, visibly at the guarded poles, which could not occur according to any acknowledged principle, unless the copper wire acted the part of a pole in each glass.—This experiment by being prolonged led me to the following:—

47. A piece of copper (bell) wire being inserted in distilled water in which a guarded pole was placed, by passing a number of slight electric shocks through the same (as above) in fifteen or twenty minutes turning, *the copper wire itself became covered with bubbles of gas,* decomposition proceeding at the guarded poles as usual, (40.43). The same also occurred by the agency

of the current alone. The results of this experiment apparently so contradictory of that in which the *guarded* pole of too great magnitude (26) was employed; where decomposition could not be effected by platina wire reduced to a moderately fine point (and which I have frequently attempted with similar results) induced me to believe that the decomposing effect was due to the agency of the guarded pole, and (with 45) led me to the following conclusion which I believe will still remain correct.

48. By the use of the *guarded poles*, or indeed *any* which perse. are capable of effecting aqueous decomposition, the ordinary electricity appears to be placed (with the exception of slightly increased tension) (17.b) in the entire condition of the galvanic fluid. Remote polarization (13.14) is by this means exchanged for atomic (5). Its expansive state reduced to the concentrated (17.c) tension exchanged for intensity, or quantity in a given amount of matter.

49. Entertaining this view of the subject I arranged three wine glasses A. B. C. fig. 2, filled with distilled water, so as to form a line between the wire soldered to the positive conductor, and that proceeding in the same manner from the negative. Into A I inserted a guarded pole g in connection by a mercury cup with the positive wire. In C I also placed a second guarded pole g. The view I had taken (48) led me to conclude that if the positive, and negative currents were introduced by poles capable of effecting decomposition, the fluid being thus placed in the condition of galvanic, whatever might be the nature of the intervening poles, if capable of decomposing by galvanism, they would also perform the same by this means, provided that a sufficient quantity of electric fluid was supplied by the introducing poles. Two common platina wires e. f. (the latter of considerable thickness) were bent at right angles at their extremities, and placed in a line between the guarded poles—their terminations being inserted about one-eighth of an inch below the surface of the water in the glasses, and a slight distance from each other and the guarded poles—one end of e being in A, the opposite in B,—one termination of f in B, the opposite in C. On turning the machine for about *five minutes*, *very minute bubbles began to make their appearance on the inserted termination of each wire*. In from *ten to twenty minutes*, very considerable bubbles were formed, as visible and distinct as in any galvanic decomposition, which also commenced ascending from the surface of the wires. Thus we have a perfect decomposition of water by the *current alone*, effected in the central glass B, by *two unprepared and moderately thick platina wires, as truly as by galvanic agency*.

I next arranged a piece of copper bell wire between B and C instead of the wire f. *Decomposition became visible by the*

deposition of bubbles on this also, but from its magnitude requiring a longer period of turning. (Dec. 19, 1840.)

50. I now proceed to introduce the currents into the glasses A and C, without any guarded pole whatever. In A, a thin copper wire was inserted about one-eighth of an inch, in connexion with the positive conductor. From A to B one of the former platina wires e, and between B and C, the other f inserted as formerly. The pole from the negative mercury cup being a thick bell wire, inserted about the same depth. In two minutes and a half, gas was evident upon every termination, especially upon the C end of f. This experiment is exceedingly remarkable when contrasted with the attempt at decomposition by guarded poles (26.)

51. Having observed so unexpected and rapid decomposition in the last, I determined to attempt the experiment by two thick unguarded wires, inserted in a single wine glass. I placed about one-eighth of an inch of each of the copper (bell wire) poles proceeding from the positive and negative conductors of the electrical machine in distilled water. In three minutes (the revolutions of the cylinder being about 60 per minute) one or two bubbles manifested themselves upon the termination of each wire, and by the microscope, smaller ones could be seen all over the inserted surface of each. In five minutes distinct bubbles were seen by the naked eye, upon all parts of the wires below the water, assuming a frosted appearance, and about double the quantity upon the negative pole. In half an hour the covering, especially of the negative pole, might be seen at the distance of two yards, and as fair an electro-chemical effect, as is ever observed by voltaic electricity.

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